# U. S. NAVAL SUBMARINE MEDICAL CENTER

## Submarine Base, Groton, Conn.

REPORT NUMBER 549

# SALIVARY ACID-BASE LEVELS DURING EXPOSURE TO AN ELEVATED CARBON DIOXIDE ATMOSPHERE

by

LT Robert M. Lambert, MC, USN

and

CDR William R. Shiller, DC, USN

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MR005.19-6024.08

Released by:

Gerald J. Duffner, CAPT MC USN
COMMANDING OFFICER
Naval Submarine Medical Center

11 October 1968

# SALIVARY ACID-BASE LEVELS DURING EXPOSURE TO AN ELEVATED CARBON DIOXIDE ATMOSPHERE

by

LT Robert M. Lambert, MC, USN

and

CDR William R. Shiller, DC, USN

SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 549

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MR005.19-6024.08

Reviewed and Approved by:

Charles F. Gell

Charles F. Gell, M.D., D.Sc.(Med)
SCIENTIFIC DIRECTOR
SubMedResLab

Reviewed and Approved by:

Joseph D Bloom

J. D. Bloom, CDR, MC, USN
DIRECTOR
SubMedResLab

Approved and Released by:

Gerald J. Duffner

Gerald J. Duffner
Captain, MC, U.S. Navy
COMMANDING OFFICER

# SUMMARY PAGE


## THE PROBLEM

Dental diseases, including periodontal disease, have at times proved to be vexacious health problems on submarine patrols. Dental calculus is thought to play a role in periodontal disease. Little is known about the oral factors on patrol which may influence the calculus rate. Past studies indicate that the salivary pH may have a role in this formation. A knowledge of oral pH changes on patrol was needed to help understand the dental calculus formation rate.

## FINDINGS

Of the 25 crewmen tested, 19 had elevations of pH on patrol which were statistically significant when compared with the pre-patrol values. The t-test was used for comparison.

## APPLICATIONS

The fact that salivary pH is increased in an atmosphere where the proportion of carbon dioxide is higher than in normal air should direct more studies toward correlating this factor with other salivary components and calculus formation rates.



ADMINISTRATIVE INFORMATION

This study was conducted in conjunction with the Dental Branch, Submarine Medical Research Laboratory, as a partial fulfillment of requirements for qualification of LT Robert M. Lambert, MC, USN, as a submarine medical officer.

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MR005.19-6024—Effect of Stresses of Submarine Service on Oral Health. This report has been designated as Submarine Medical Research Laboratory Report No. 549. It is Report No. 8 on this Work Unit, and was approved for publication as of 11 October 1968.





PUBLISHED BY THE NAVAL SUBMARINE MEDICAL CENTER

## ABSTRACT

Dental diseases, including periodontal disease, at times become vexacious health problems on submarine patrols. Dental calculus is thought to play a role in periodontal disease. Little is known about the oral factor on patrol which may influence the calculus formation rate. Past studies indicate that the salivary pH may have a role in this formation. The saliva from the anterior sublingual pool of 25 crew members of a Polaris submarine was collected on each of six successive days before patrol and on the 31st through the 36th days of patrol. Of the 25 men tested, 19 had pH elevations on patrol which were statistically significant when compared with the pre-patrol values. It is concluded that on patrol changes do occur in salivary characteristics which are worth further study in examining salivary component and calculus relationships.

# SALIVARY ACID-BASE LEVELS DURING EXPOSURE TO AN ELEVATED CARBON DIOXIDE ATMOSPHERE

## INTRODUCTION

The role of dental calculus in periodontal disease has been the subject of some controversy. The mechanical irritating effect of calculus on the soft tissue has often been cited in dental textbooks.[1] The injurious effect of calculus may be in the roughened surface it provides for the accumulation of harmful bacterial plaque.[2] Regardless of the precise mechanisms of its action, the relationship between dental calculus and periodontal disease has long been a matter of record.[3,4,5]

There are several ideas concerning the mechanisms of calculus formation. One of the major ones is the physiochemical theory which, briefly, is based upon an elevation of the salivary pH and a resulting precipitation of calcium and phosphates onto an organic matrix of the teeth. It is recognized that the salivary pH is of prime importance in this system. Since the oral health of Fleet Ballistic Missile (FBM) sailors is of extreme importance,[6] it seemed desirable to evaluate this prime factor in calculus formation—namely, the pH of the pooled saliva of the oral cavity.

## MATERIALS AND METHODS

Twenty-five crew member volunteers were selected for this study from the Blue Crew of the USS PATRICK HENRY (SSBN 599). A salivary specimen was collected on each of six successive days immediately prior to patrol and again on the 31st through the 36th days of patrol in the following manner: The men were instructed to swallow all saliva in their mouth. They then bent their heads forward for 45 seconds to facilitate the collection of saliva in the anterior pool. The anterior pool was selected because of its supposed effect on calculus formation. At the end of the 45 seconds they were instructed to expectorate into a 50 milliliter beaker. The pH was immediately measured with a Type-G Beckman pH meter, utilizing a single probe electrode. It was found that if the pH was not immediately measured, the readings increased slightly.

The pH meter was standardized using buffer of 6.8 and 9.0 measured at the appropriate temperature. The subjects' samples were all measured at 28°C.

The diet, both before patrol and on patrol, was approximately equivalent; the only known variable of importance being the increased carbon dioxide ($CO_2$), averaging one percent on patrol.

The specimens were taken either in the morning or afternoon and the subjects were instructed not to eat or drink for at least one hour prior to the collection. No other special restrictions were imposed.

## RESULTS

Comparison of the prepatrol and patrol means of each individual was accomplished by use of the t-test:

$$t = \frac{M_1 - M_2}{\sqrt{(S_{x_1})^2 + (S_{x_2})^2}}$$

Any t value corresponding to a probability value of less than .05 was considered to be statistically significant.

Comparison of the population mean differences (prepatrol and patrol) was accomplished by use of the t-test for paired data, since each man served as his own control:

$$\frac{t = d}{S_d}$$

It was found that the mean difference was $+.301 \pm .032$ which is highly significant ($P < .0001$).

The data are presented in Table I. It is noted first that the variability was very small as evidenced by the low standard deviation values. With only six exceptions, there were significant increases in the salivary pH on patrol compared with the prepatrol values. Only one individual showed a decrease in pH.

Table I

| Subject | Prepatrol Mean | Patrol Mean | Mean Difference (Patrol-Prepatrol) | Probability |
|---|---|---|---|---|
| 1 | 6.53 ± .207+ | 6.91 ± .115 | +.38 | ** |
| 2 | 6.48 ± .247 | 6.95 ± .096 | +.47 | ** |
| 3 | 6.53 ± .186 | 7.03 ± .175 | +.50 | ** |
| 4 | 6.42 ± .233 | 6.61 ± .067 | +.19 | N.S. |
| 5 | 6.60 ± .248 | 6.85 ± .077 | +.25 | * |
| 6 | 6.28 ± .135 | 6.75 ± .181 | +.47 | ** |
| 7 | 6.55 ± .221 | 6.93 ± .112 | +.38 | ** |
| 8 | 6.53 ± .265 | 6.97 ± .075 | +.44 | ** |
| 9 | 6.64 ± .163 | 6.80 ± .111 | +.16 | N.S. |
| 10 | 6.47 ± .028 | 6.65 ± .090 | +.18 | ** |
| 11 | 6.66 ± .174 | 6.91 ± .140 | +.25 | * |
| 12 | 6.09 ± .163 | 6.20 ± .201 | +.11 | N.S. |
| 13 | 6.52 ± .193 | 6.88 ± .123 | +.36 | ** |
| 14 | 6.32 ± .269 | 6.63 ± .161 | +.31 | * |
| 15 | 6.29 ± .177 | 6.91 ± .110 | +.62 | ** |
| 16 | 6.51 ± .016 | 6.88 ± .170 | +.37 | ** |
| 17 | 6.53 ± .210 | 7.01 ± .021 | +.48 | ** |
| 18 | 6.53 ± .211 | 6.79 ± .126 | +.26 | * |
| 19 | 6.58 ± .219 | 6.76 ± .226 | +.18 | N.S. |
| 20 | 6.44 ± .164 | 6.60 ± .029 | +.16 | * |
| 21 | 6.43 ± .291 | 6.62 ± .230 | +.19 | N.S. |
| 22 | 6.60 ± .028 | 6.84 ± .130 | +.24 | ** |
| 23 | 6.60 ± .125 | 6.40 ± .105 | -.20 | ** |
| 24 | 6.44 ± .141 | 6.83 ± .026 | +.39 | ** |
| 25 | 6.59 ± .174 | 6.98 ± .017 | +.39 | ** |

+Standard deviation

*$P < .05$

**$P < .01$

## DISCUSSION

This study was initiated to gather some basic information regarding the oral environment. From this information we will make some assumptions concerning calculus formation and hopefully stimulate more study in the field.

Calcium phosphate ($CaPO_4$) is assumed to be a major factor in calculus formation.[7] Although numerous theories have been proposed concerning the mechanism, none of these exclusively and completely explain the phenomena.

The present study is interested in the physicochemical theory. As summarized by Hodge and Leung:[8] "It is postulated (a) that for each ratio of calcium and phosphorus in the saliva there is a critical pH above which precipitation will occur, and (b) that the elevation of the pH of the secreted saliva above the critical level is brought about through the loss of $CO_2$." Likewise, Little, Swan and Schlueter[9] in a study on remineralization of dental calculus, showed that a solution with a higher pH was more effective in inducing mineralization than the same solution with a lower pH for most common calcium phosphorus ion products.

Von der Fehr and Brudevold's work[7] with calculus formation at increased $CO_2$ levels showed a decrease in the rate of formation if the $CO_2$ content was held constant or increased. From this it could be inferred that the submarine atmosphere, with its increased $CO_2$ levels, should lead to a decrease in calculus formation. However, a recent study by Piebenga and Shiller[10] showed no significant change in the rate of calculus formation.

Hughes[11] noted a low order increase in parotid salivary $CO_2$. From this he concluded the body's compensation to high ambient $CO_2$ does not result in a great change in parotid saliva $CO_2$ content.

The present study showed a significant increase in the pH levels in an elevated $CO_2$ atmosphere. From these data, one could assume that the change in pH is a result of the same compensatory mechanism which produces an alkaline urine[12] and is not due to a post secretory $CO_2$ loss.

There are really two possibilities open to us with regard to the interpretation of these pH findings.

1. An elevated pH of saliva will result in an increased precipitation of calculus; therefore, an increased calculus formation rate should be expected on FBM patrols.

2. An elevated pH is of importance in calculus formation only when this rise occurs from the loss of $CO_2$ after salivary secretion. If the high pH values are the result of decreased secretion of $CO_2$, then there should be no increase in calculus formation rate. There may even be a decreased rate because of the high ambient $CO_2$ on FBM patrols.

A study is being planned by this worker involving a repeat of the pH measurements, a measurement of the calculus formation by the Volpe-Manhold method,[13] and the collection of whole saliva samples for chemical analyses. Only through such a complete study can a choice be made between the above two possibilities.

## SUMMARY

1. Measurements of the anterior salivary pool pH on a Polaris patrol revealed a statistically significant increase in nineteen of twenty-five subjects when compared to prepatrol values.

2. The elevated salivary pH could be assumed to increase the calculus formation rate. One prior study showed no change in the rate of calculus formation. However, with a new and more sensitive method, small changes might be demonstrated.

3. Further studies are necessary to elucidate this relationship between salivary pH and calculus formation.

## REFERENCES


1. Glickman, I. **Clinical Periodontology**, 2nd ed., Saunders, Philadelphia, 1963, pp. 321-322.
2. Leung, S. Wah. The relation of calculus plaque and food impaction to periodontal disease. **J. Dent. Res.** 41:306-311, 1962.
3. Ramfjord, S. P. The periodontal status of boys 11 to 17 years old in Bombay, India. **J. Periodont.** 32:237-248, 1961.
4. Greene, J. C. and Vermillion, J. R. The oral hygiene index. A method for classifying oral hygiene status. **J. Am. Dent. Assoc.** 61:172-179, 1960.
5. Shiller, W. R. Periodontal health of submarine school candidates: A correlative analysis. **J. Periodont.** 37:224-229, 1966.
6. Shiller, W. R. Incidence of dental problems and their management on FBM submarine patrols. **SMRL Memo Rept.** 67-4, 17 April 1967.
7. Von der Fehr, F. and Brudevold, F. In vitro calculus formation. **J. Dent. Res.** 39:1041-1048, 1960.
8. Hodge, H. C. and Leung, S. W. Calculus formation. **J. Periodont.** 21:211-221, 1950.
9. Little, M. R., Schlueter, G. and Swan, S. Factors influencing the remineralization of dental calculus. **J. Dent. Res.** 45:801-811, 1966.
10. Piebenga, L. W. and Shiller, W. R. Dental calculus formation rate in a submarine environment. Submarine Qualification Thesis, **Submarine Medical Research Laboratory**, SubMedCen, Groton, Conn.., 1967.
11. Hughes, M. Salivary $CO_2$ and electrolyte secretion during exposure to an elevated $CO_2$ atmosphere. Submarine qualification thesis, **Submarine Medical Research Laboratory**, SubMedCen, Groton, Conn., 1966.
12. Schaefer, K. E., Nichols, G., Jr., and Carey, C. R. Calcium phosphorous metabolism in man during acclimatization to $CO_2$. **J. Appl. Physiol.** 18:1079-1084, 1963.
13. Volpe, A. R., Manhold, J. H. and Hazen, S. P. In vivo calculus assessment: Part I. A method and its examiner reproducibility. **J. Periodont.** 36:292-298, 1965.

UNCLASSIFIED

Security Classification

## DOCUMENT CONTROL DATA - R & D

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author)<br>NAVAL SUBMARINE MEDICAL CENTER, Submarine Medical Research Laboratory | 2a. REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED<br>2b. GROUP<br>N/A |

3. REPORT TITLE

Salivary Acid-Base Levels During Exposure to an Elevated Carbon Dioxide Atmosphere

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim Report

5. AUTHOR(S) (First name, middle initial, last name)

Robert M. Lambert, LT MC USN
William R. Shiller, CDR DC USN

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| 11 October 1968 | | 13 |

| | |
|---|---|
| 8a. CONTRACT OR GRANT NO.<br><br>b. PROJECT NO.<br>MR005.19-6024.08<br>c.<br><br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>Submarine Medical Research Laboratory Report No. 549<br><br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) |

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY |
|---|---|
| | Naval Submarine Medical Center,<br>Box 600, Naval Submarine Base<br>Groton, Connecticut 06340 |

13. ABSTRACT

Dental diseases, including periodontal disease, have at times proved to be health problems on submarine patrols. Dental calculus is thought to play a role in periodontal disease. Little is known about the oral factor on patrol which may influence the calculus formation rate. Past studies indicate that the salivary acidity (pH) may have a role in this formation. The saliva from the anterior sublingual pool of 25 crew members of a Polaris submarine was collected on each of six successive days before patrol and on the 31st through the 36th days of patrol. Of the 25 men tested, 19 had acidity (pH) elevations on patrol which were statistically significant when compared with the pre-patrol values. It is concluded that on patrol changes do occur in salivary characteristics which are worth further study in examining salivary component and calculus relationships.

| 14 KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Whole saliva | | | | | | |
| Salivary acidity (pH) | | | | | | |
| Submarine environment | | | | | | |